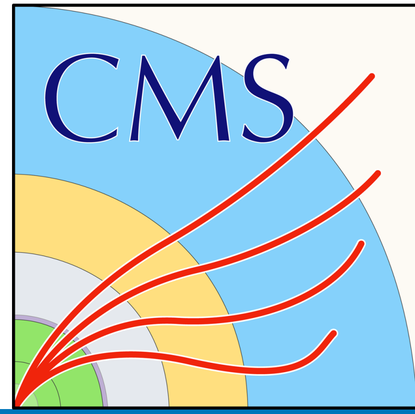
Search for new physics with long-lived and unconventional signatures in CMS

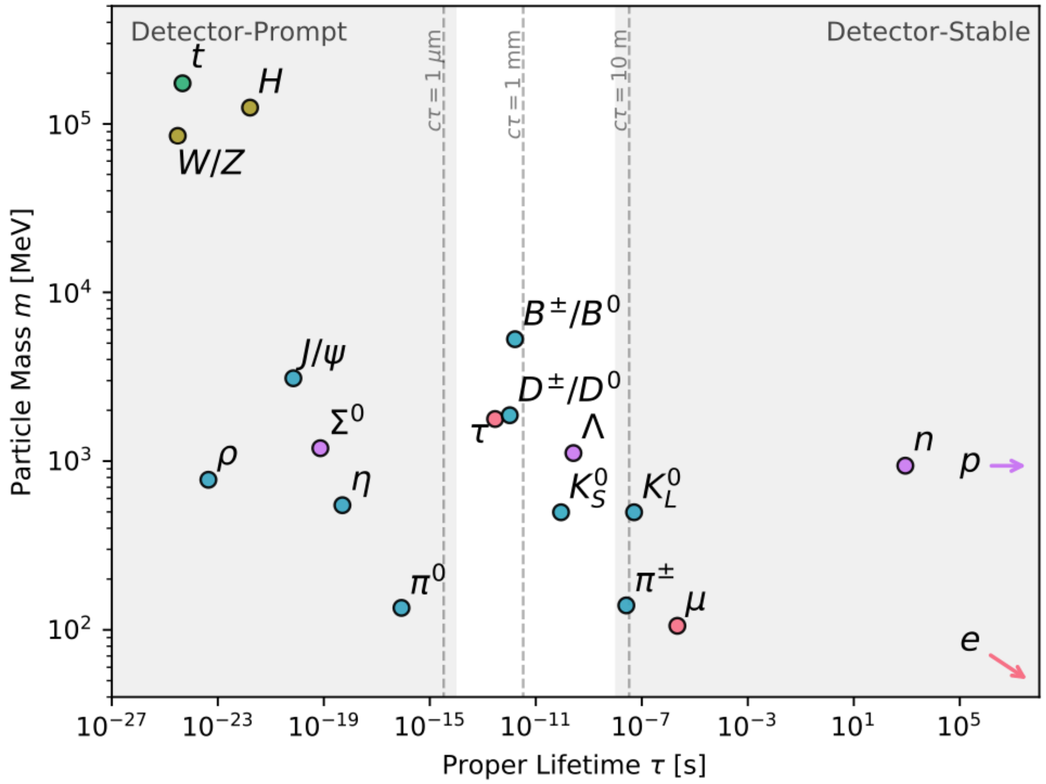
31st International Symposium on Lepton Photon Interactions at High Energies

Daniel Diaz on behalf of the CMS Collaboration



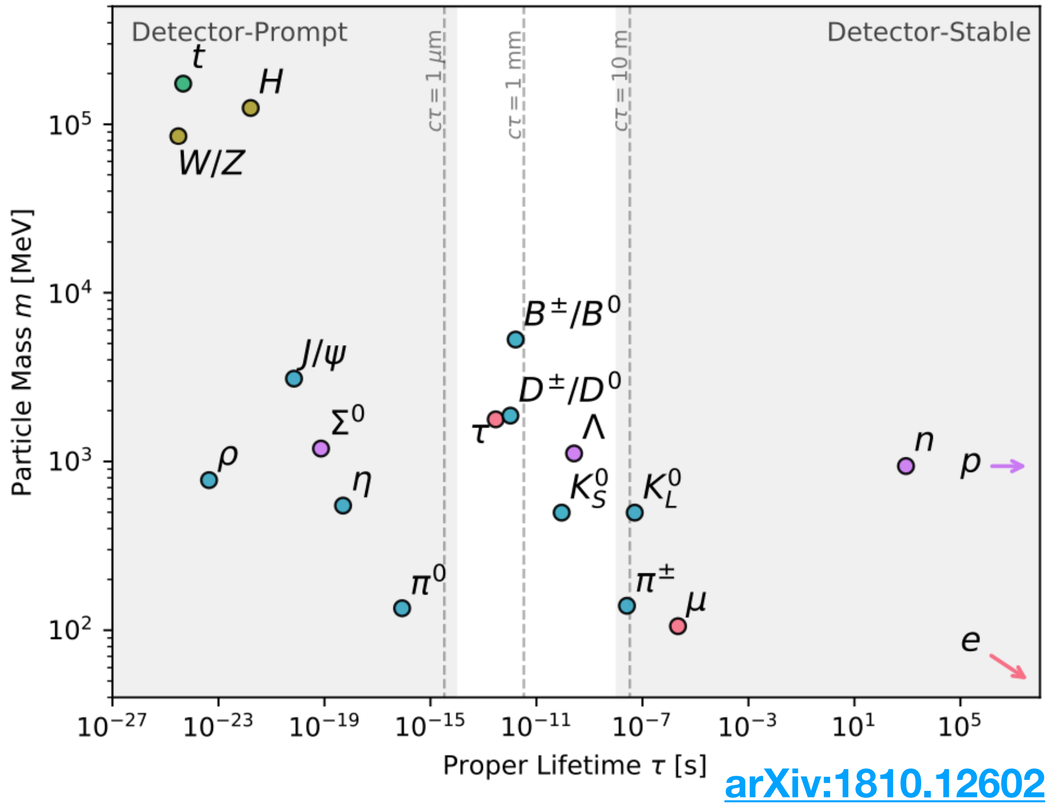
Long-lived Particles (LLPs)

- We know of the existence of LLPs.
- Evidence of their existence can be seen in the standard model.

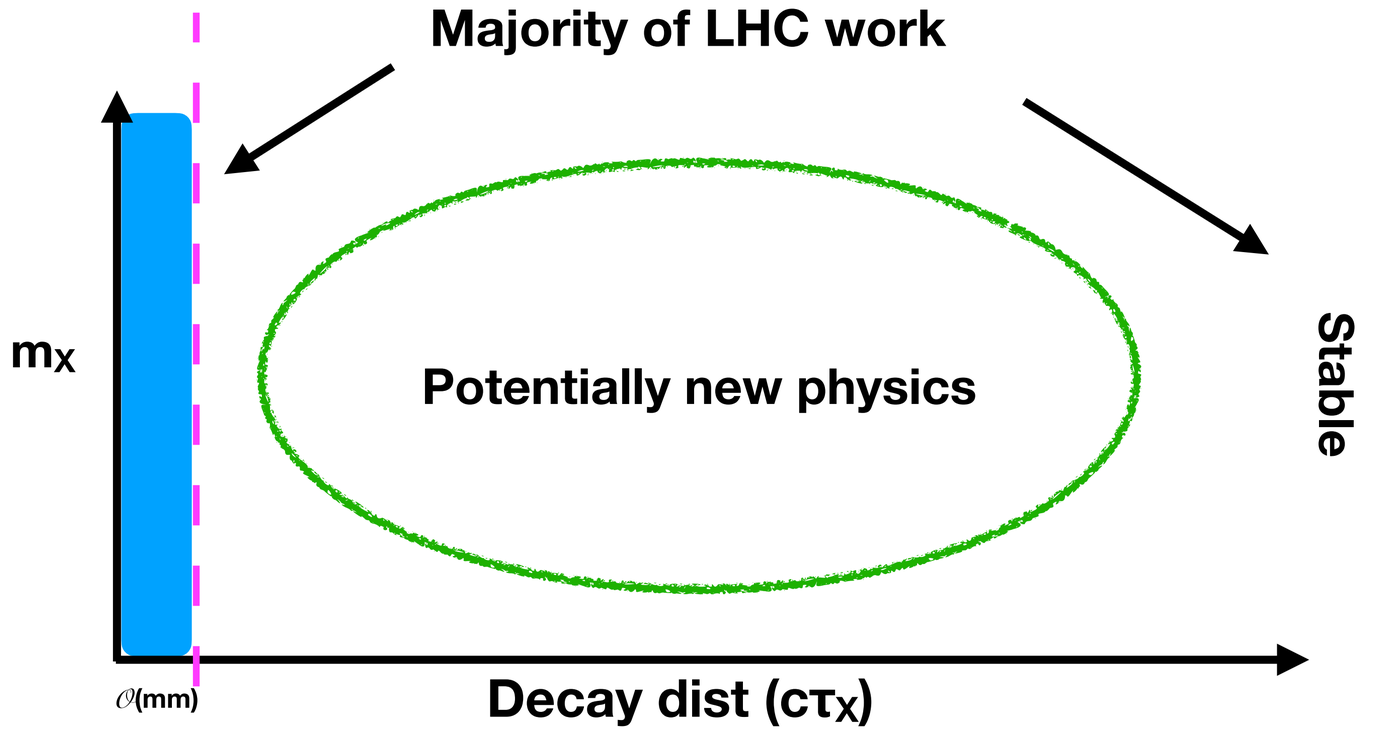


Long-lived Particles (LLPs)

- We know of the existence of LLPs.
- Evidence of their existence can be seen in the standard model.
- LHC searches predominately explore prompt objects.



arXiv:1810.12602



Credit: James Beacham

LLPs as a window to new physics

New Physics

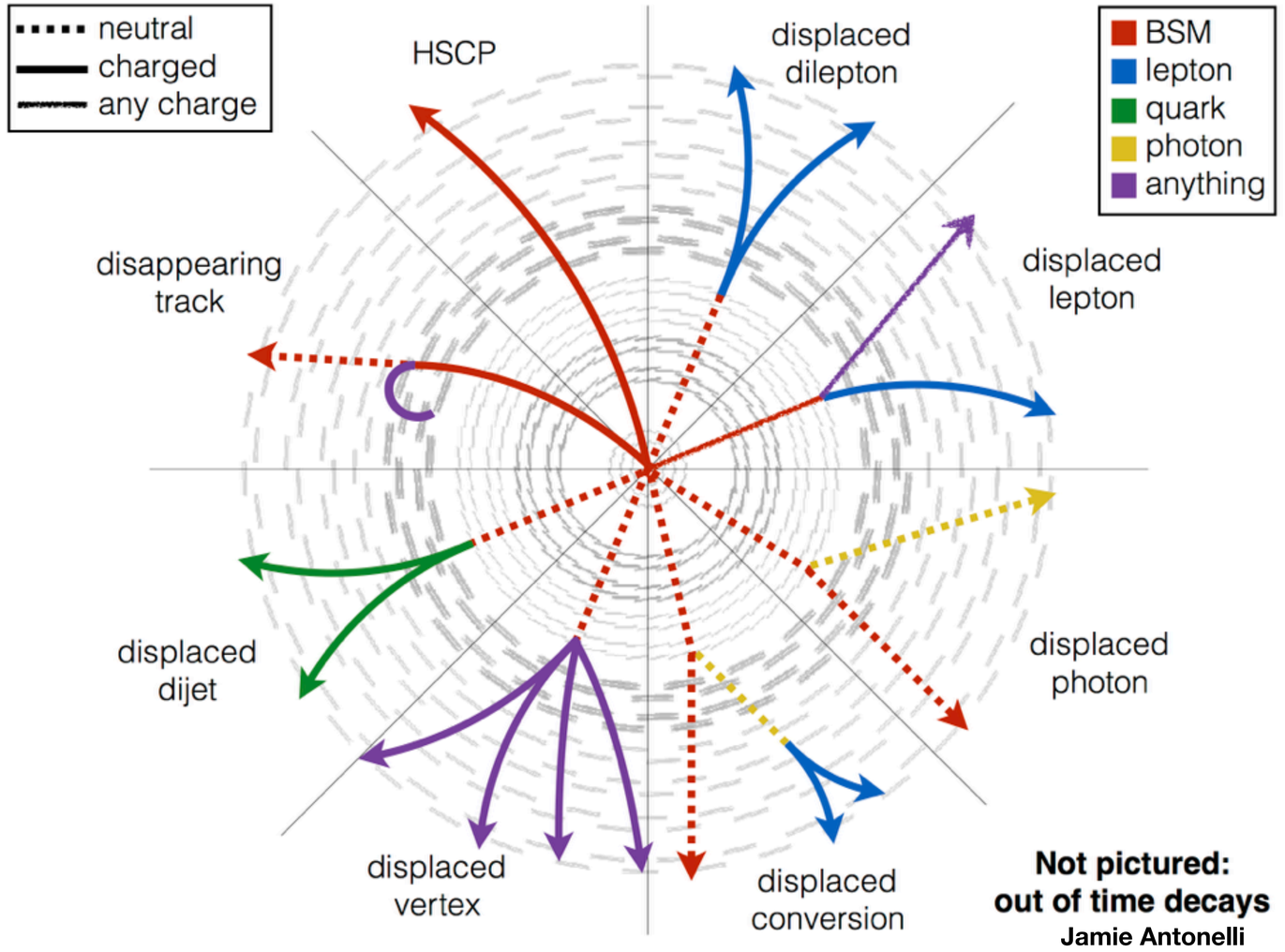
		Small coupling	Small phase space	Scale suppression
SUSY	GMSB			✓
	AMSB		✓	
	Split-SUSY			✓
	RPV	✓		
NN	Twin Higgs	✓		
	Quirky Little Higgs	✓		
	Folded SUSY		✓	
DM	Freeze-in	✓		
	Asymmetric			✓
	Co-annihilation		✓	
Portals	Singlet Scalars	✓		
	ALPs			✓
	Dark Photons	✓		
	Heavy Neutrinos			✓

Long-lived

arXiv:1810.12602

LLP Searches @CMS

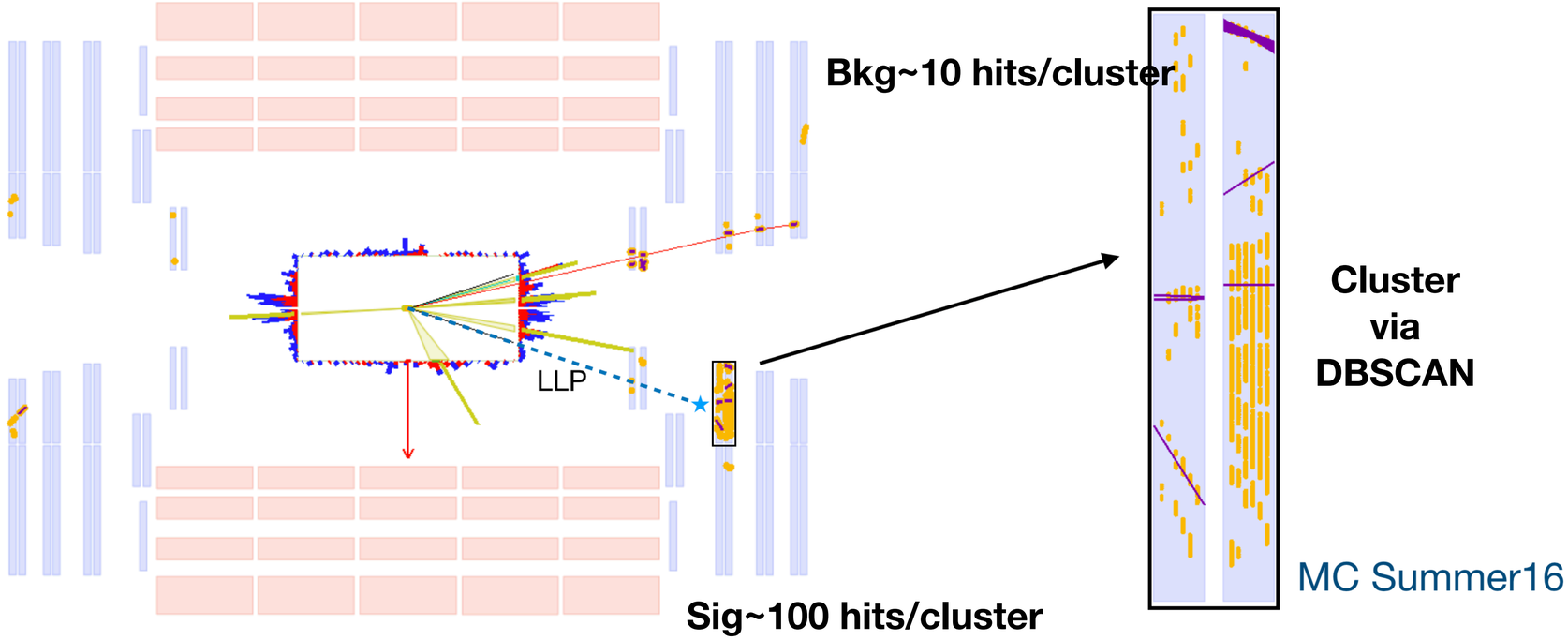
- Increased interest during Run II
  - ~45 LLP searches
- Common difficulties
  - Lack of triggers
  - Signal MC generation
  - Low level information needed for LLP reconstruction
- Rich landscape of detector signatures.
- **CMS is working in parallel on Run 2 and Run 3 results.**



Muon Detector Showers

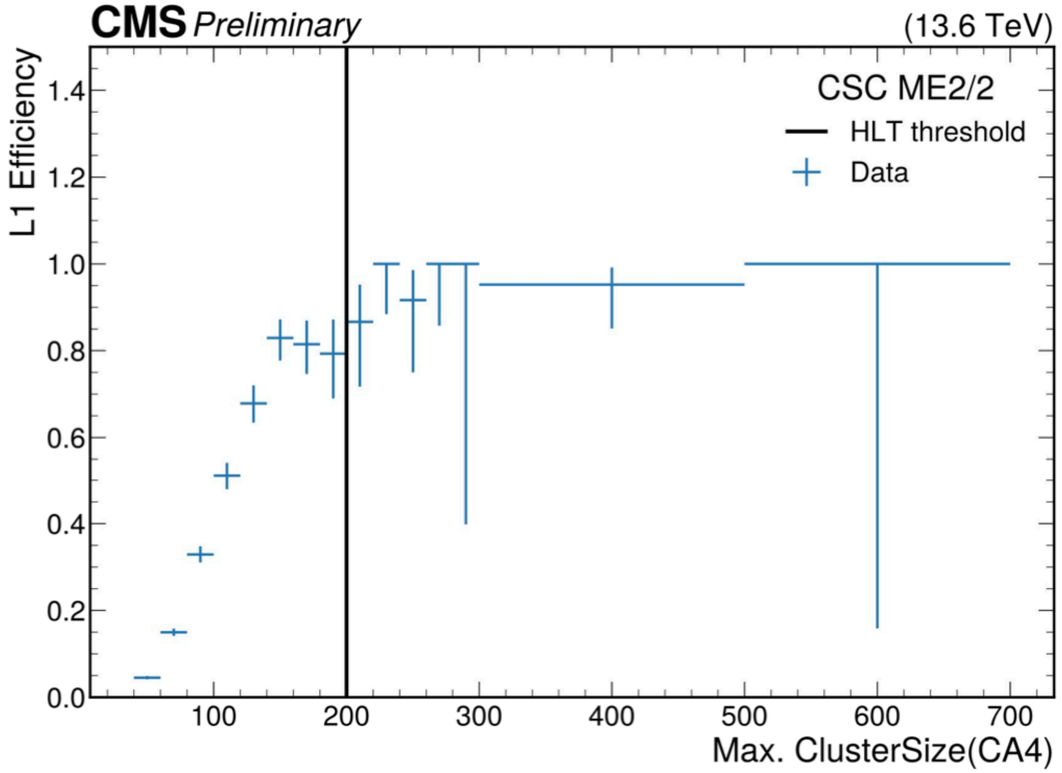
- Unique to CMS - treat muon system as a sampling calorimeter.
- LLP decays in the muon system produce high rechit multiplicity clusters.
- Sensitive to hadronic and electromagnetic showers.
- Very low background due to steel layers.
- Sensitive to longer lifetimes —> useful tool for searching for low mass LLPs.

- Common sources of bkg:
  - Punch through
  - Muon Brem
  - Cosmics
  - SM LLPs (e.g., K_L^0)
  - PileUp



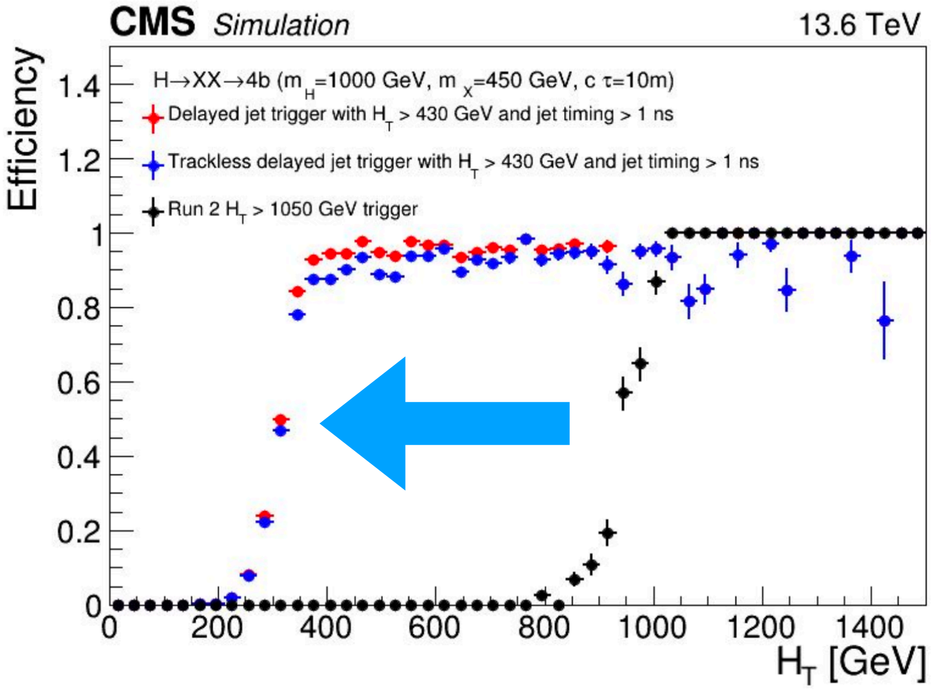
Run 3 New LLP Triggers

- **CSC high-multiplicity trigger (HMT)**
  - L1: seed to select high mult. Showers in CSCs.
  - HLT: new paths selecting events with single and double showers in muon system.
- Run 2 MDS searches relied on MET or associated production for triggering.
  - Triggering on single lepton or MET (only 1% efficiency for higgs portal)
- New LLP aware triggers in Run 3
  - Displaced Jets
  - Delayed Jets (ECAL)
  - Delayed+Displaced Jets (HCAL)
  - **CSC HMT**

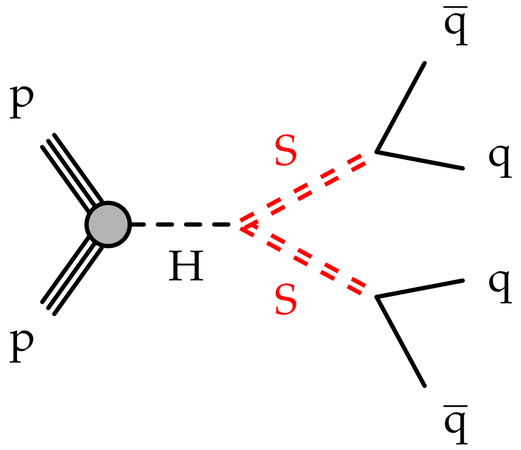


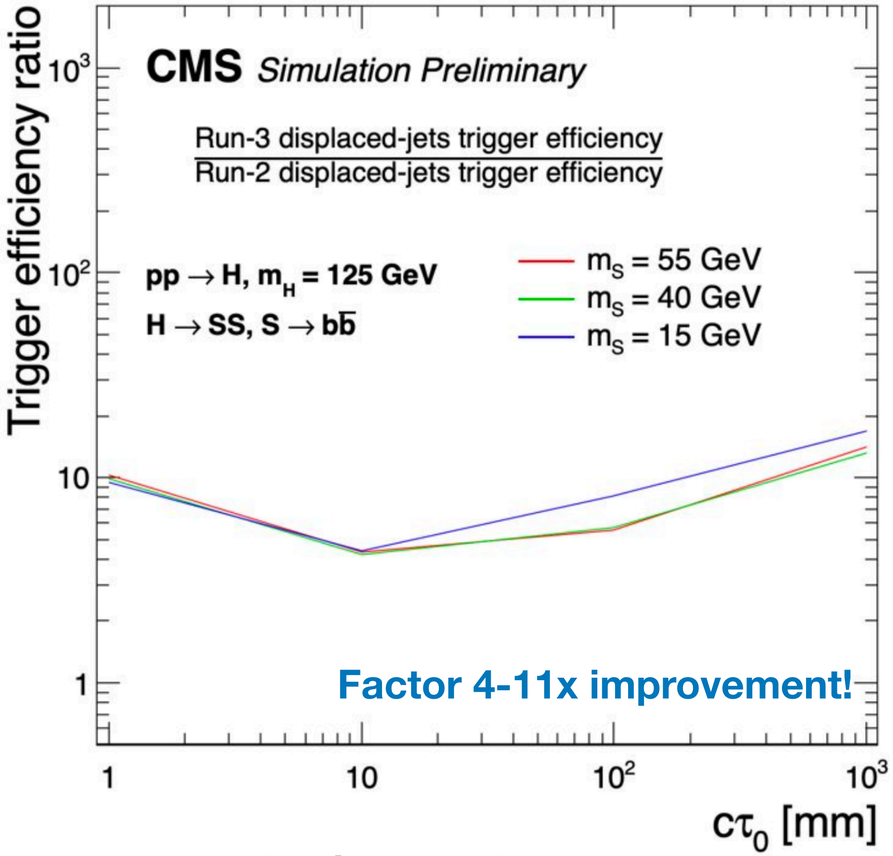
High L1 efficiency for object of interest in MDS searches

Displaced & Delayed Jets Triggers



Delayed Jets - ECAL timing



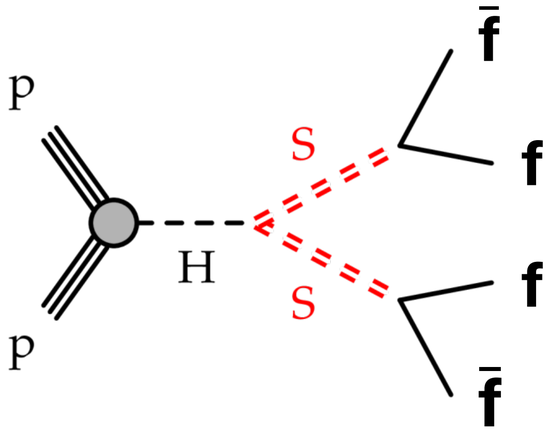


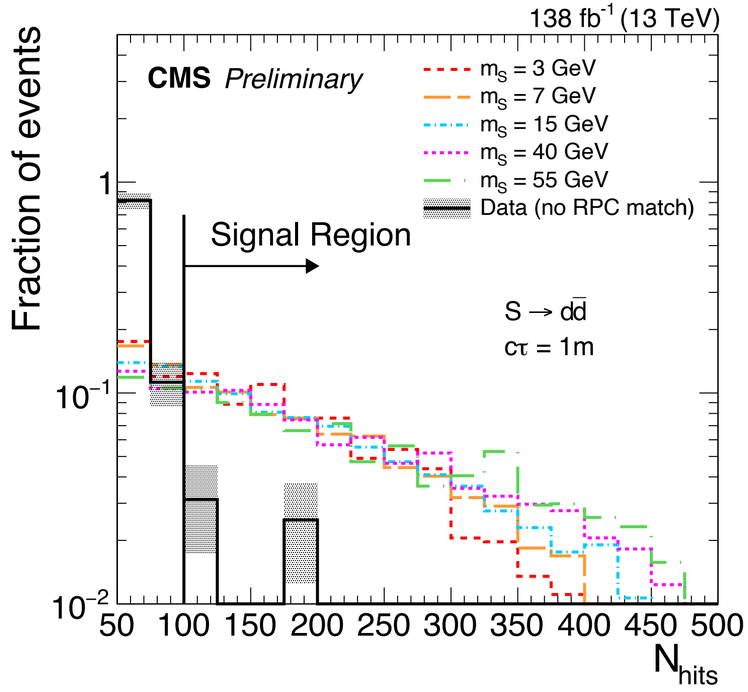
Displaced Jets - tracker

- Major improvements w.r.t. Run 2 strategies

Search for LLPs decaying in the Muon System

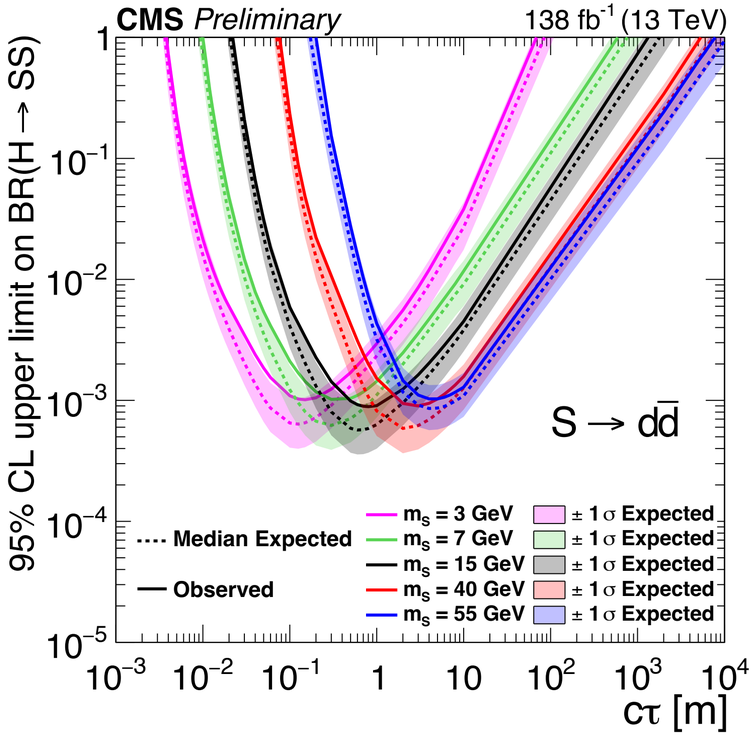
- Analysis Strategy
  - Event Selection: High MET (>200GeV)
  - Cluster Size (N_{hits}) main discriminating variable
  - Req. 1-2 clusters in the Barrel or Endcap regions.
  - 5 analysis bins based on HNL type.
- Interpretation:
  - Twin Higgs
    - Produce hadronic or EM showers in Muon System

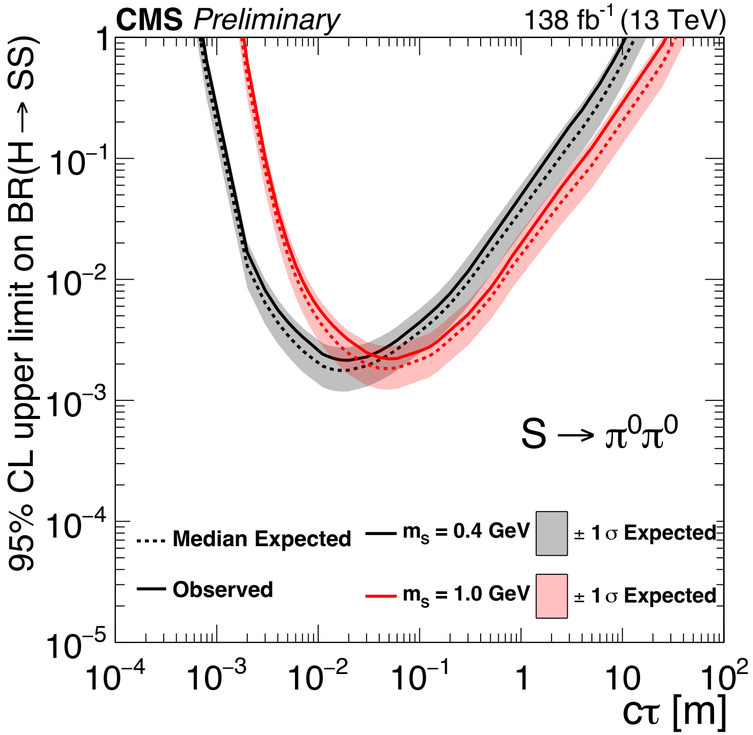


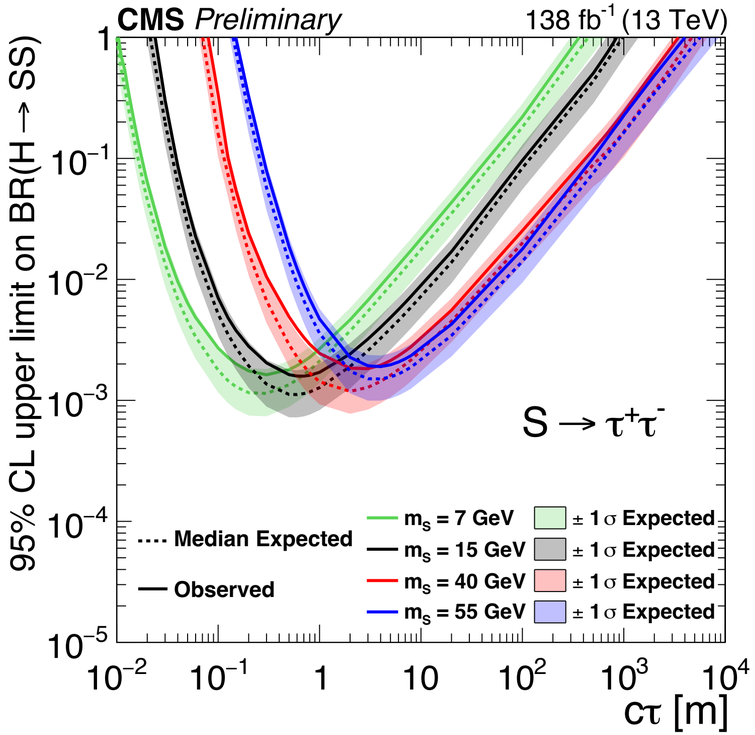


Search for LLPs decaying in the Muon System

~2x improved limits wrt CSC only result



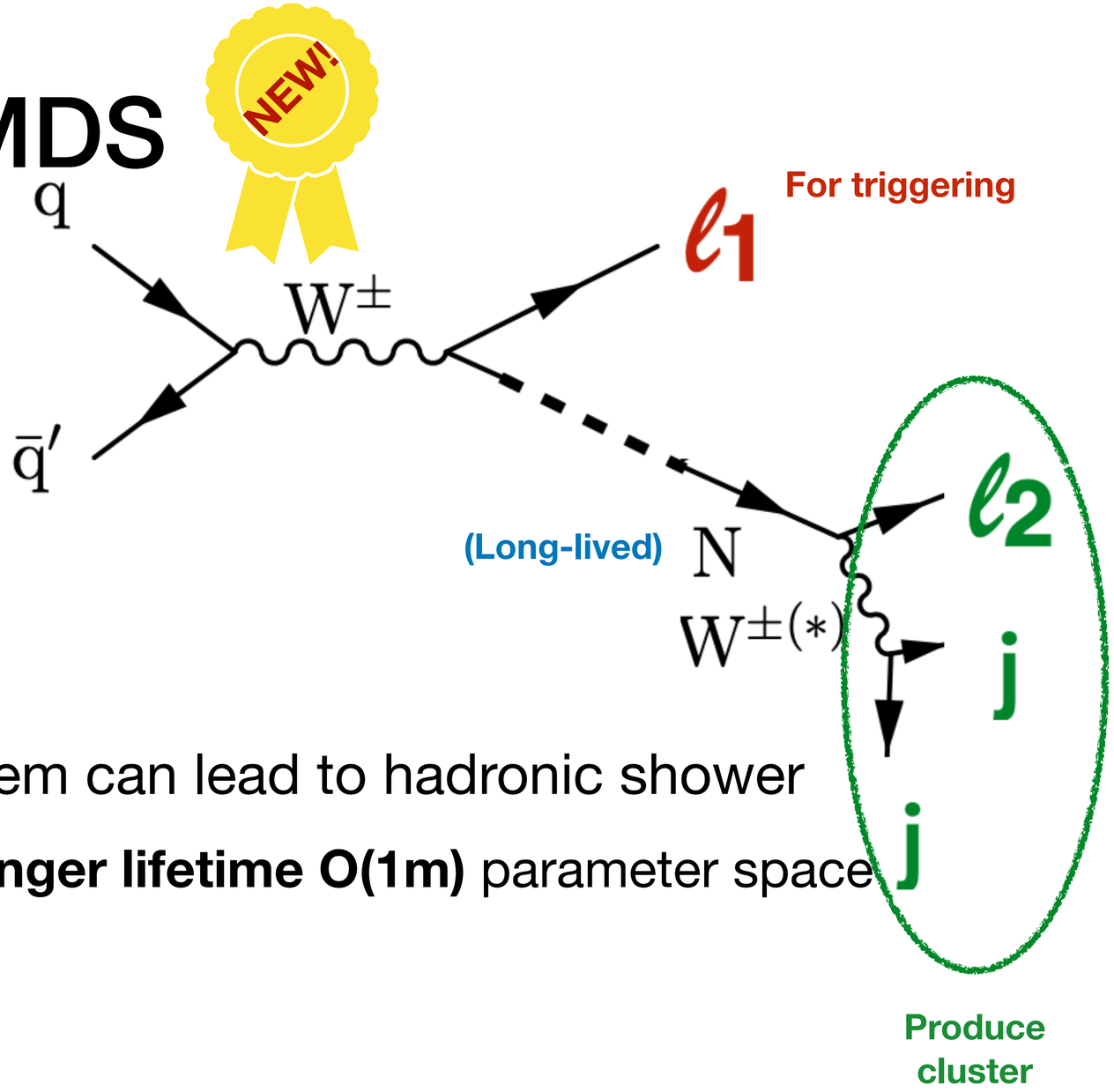




- No excess with respect to the standard model.
- Signature is sensitive to a large range of LLP masses.
- First LHC result for LLPs sensitive to sub-GeV mass.

Heavy Neutral Leptons MDS

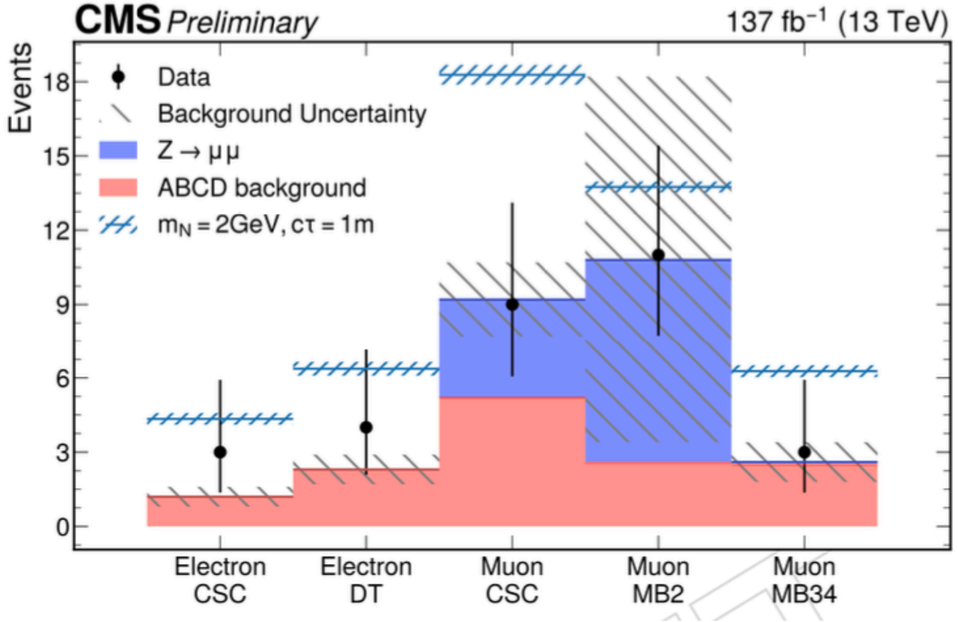
- Events selected via single lepton trigger
- HNL (N) can produce hadronic or EM showers in muon system.

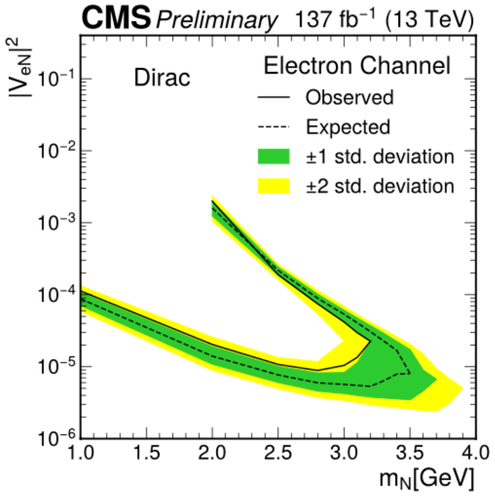


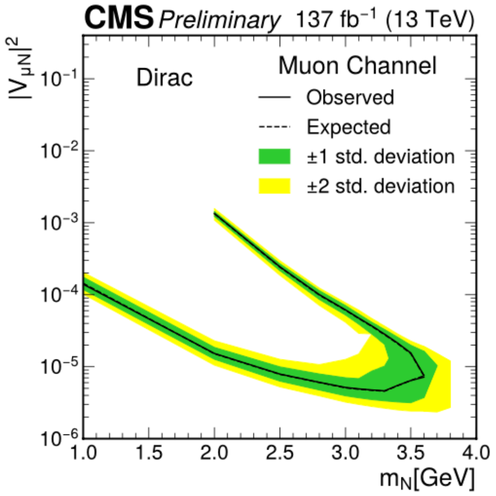
- HNL that decays in the CMS muon system can lead to hadronic shower
  - Ideal to probe **lower mass (<10GeV) / longer lifetime O(1m)** parameter space
- Targeting low mass HNLs.
- First CMS result for Tau-HNLs

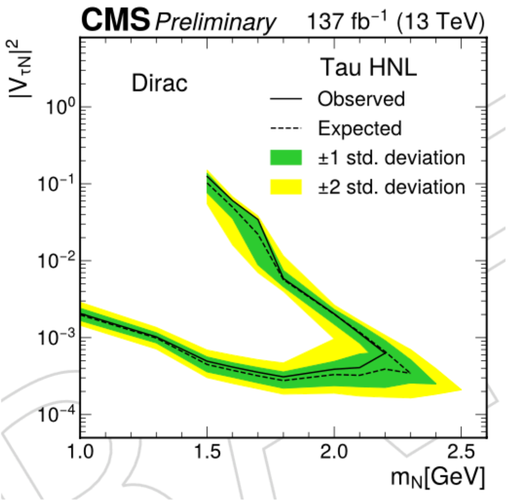
HNL MDS Results

- No significant excess observed in all 5 categories.
- Set limits on HNL couplings
  - Reaches as low as 4.6x10-6
  - Most stringent limit between HNL mass range of
    2.1-3.0 (1.6-3.3) GeV for electron (muon) couplings.
- Complimentary to existing CMS searches
  - Extends current sensitivity by ~1.3x to ~2.3x at 2GeV
  - Sensitive to all three lepton flavors







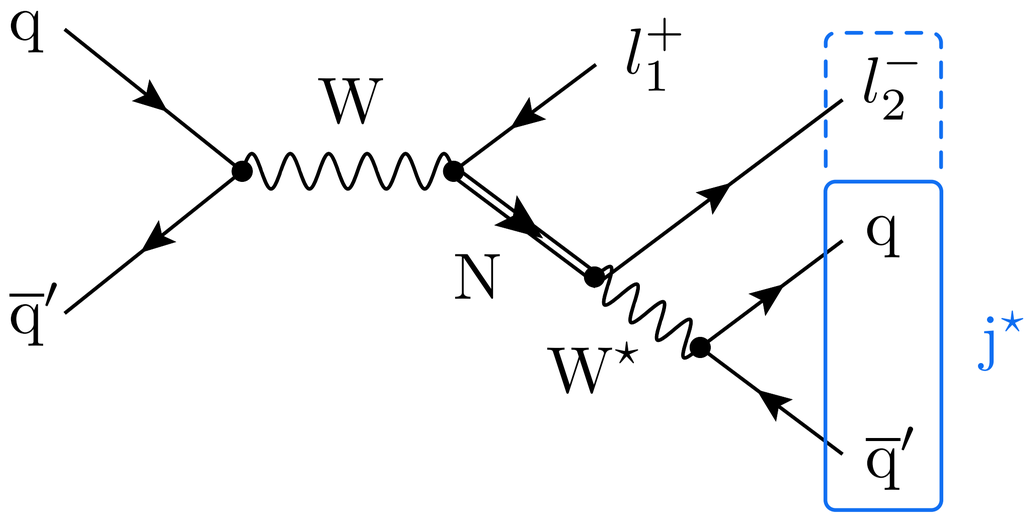


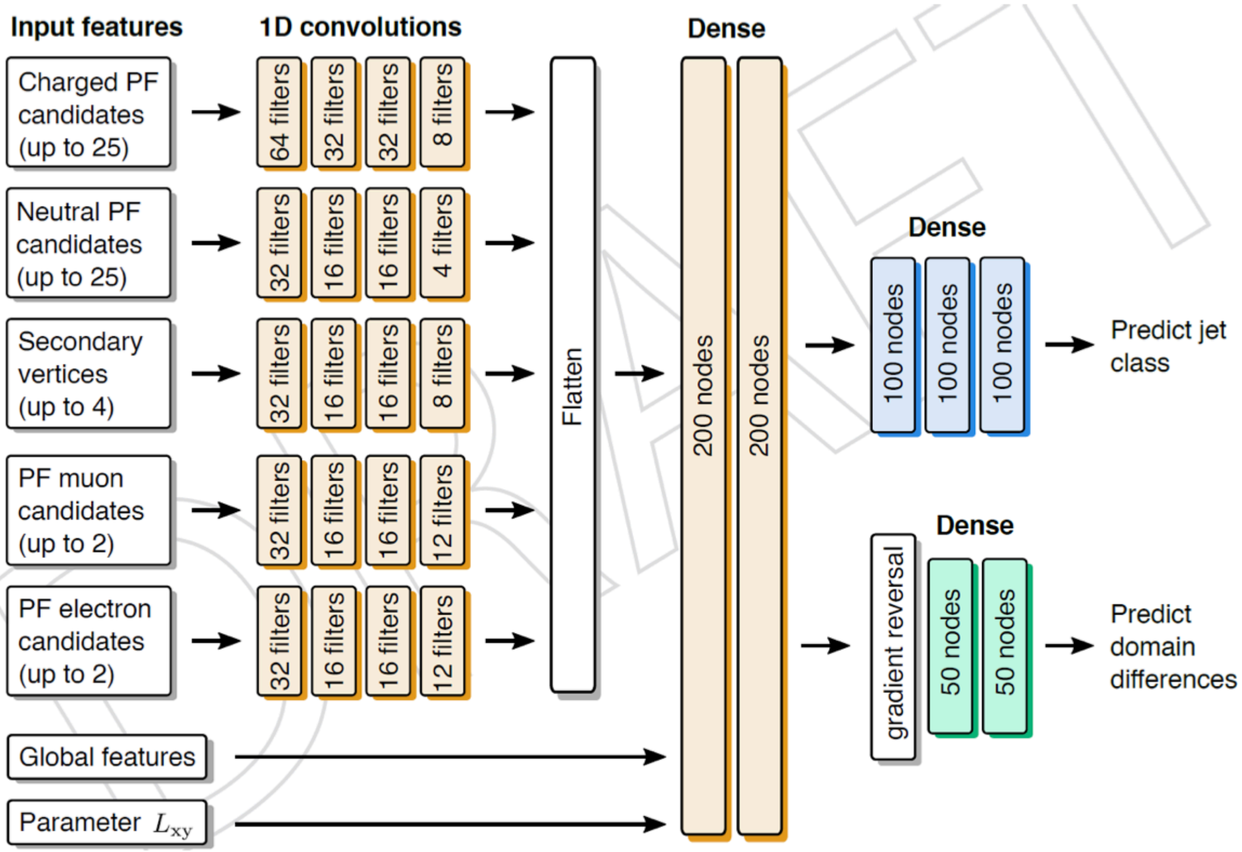
HNL (Displaced jet tagger)

- Analysis Strategy
  - Event Selection: dilepton+jets
  - Binned in 48 search regions depending on HNL scenarios

$$\underbrace{\{\text{resolved,boosted}\}}_{2} \times \underbrace{\{\text{flavour comb.}\}}_{4} \times \underbrace{\{\text{charge comb.}\}}_{2} \times \underbrace{\{\text{displacement}\}}_{3}$$

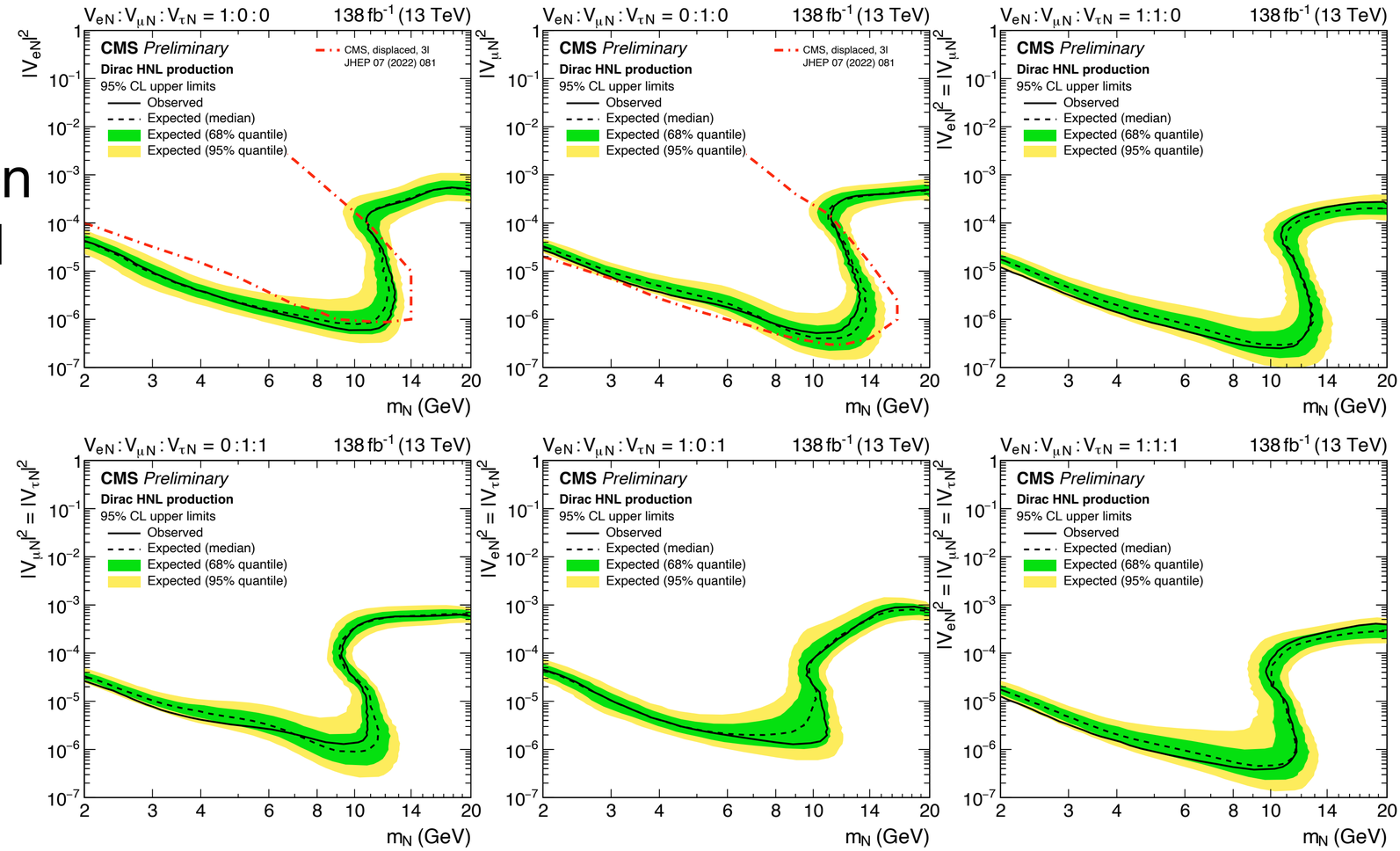
  - Dedicated displaced jet neural network tagger





HNL (Displaced jet tagger)

- No excess with respect to the Standard Model.
- Limits set for HNL cross section as a function of HNL mass and lepton coupling strength ($V_{\ell N}$).

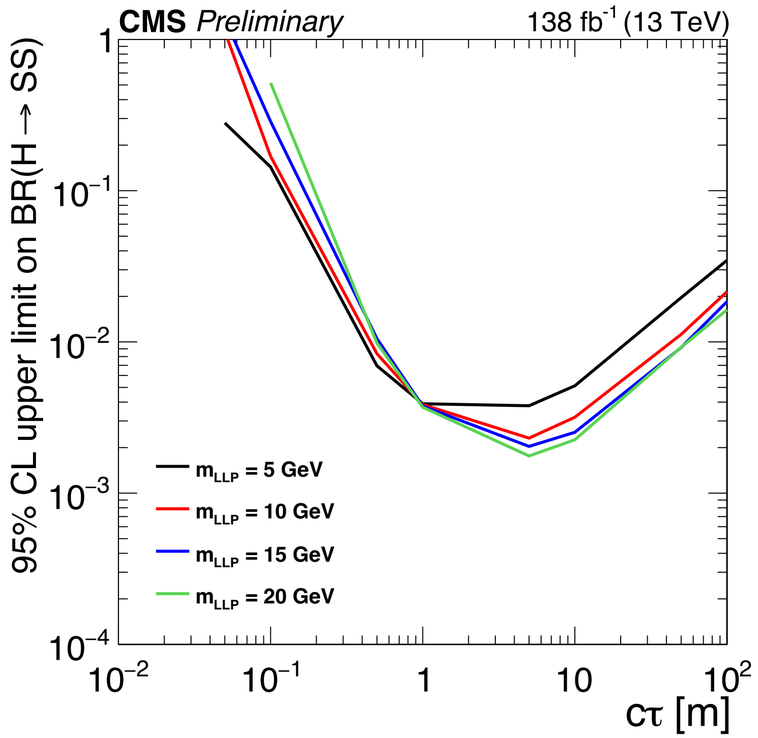


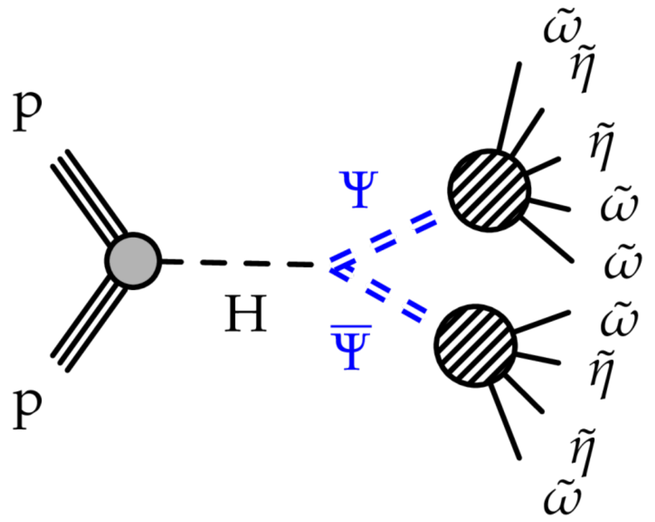
Summary

- Presented latest LLP search results from CMS
  - 2 searches released in just the past week
  - Searches employ unique techniques to overcome data challenges
    - MDS search strategy
    - ML displaced jet tagger
  - Rich program coming soon from Run 3
    - New LLP-specific HLT paths!!

Back-Up

Search for LLPs decaying in the Muon System





- No excess with respect to the standard model.
- Can also interpret results in term of h->PsiPsi
  - Psi - Dark Matter candidate